ORIGINAL ARTICLE

# Analysis of speeds in the 400-meter hurdles and gender differences: A study from the Paris 2024 Olympics

**Josivaldo de Souza-Lima** ✉. *Department of Didactics of Musical, Plastic and Corporal Expression. Faculty of Education. University of Granada. Granada, Spain.*
*Faculty of Education and Social Sciences. University Andres Bello. Santiago, Chile.*
**Frano Giakoni-Ramírez.** *Faculty of Education and Social Sciences. University Andres Bello. Santiago, Chile.*
**Catalina Muñoz-Strale.** *Faculty of Education and Social Sciences. University Andres Bello. Santiago, Chile.*
**Rodrigo Yáñez-Sepúlveda.** *Faculty of Education and Social Sciences. University Andres Bello. Viña del Mar, Chile.*
**Daniel Duclos-Bastias.** *iGEO Group. School of Physical Education. Pontifical Catholic University of Valparaíso. Valparaíso, Chile.*
*IGOID Research Group. Faculty of Sport Science. University of Castilla-La Mancha. Toledo, Spain.*
**Guillermo Cortés-Roco.** *School of Education. Sports Coaching Career. Master in Evaluation and Planning of Sports Training. University Viña del Mar. Viña del Mar, Chile.*
**Diego A. Bonilla.** *Research Division. Dynamical Business & Science Society - DBSS International SAS. Bogotá, Colombia.*
*Hologenomiks Research Group. Department of Genetics, Physical Anthropology and Animal Physiology. Faculty of Science and Technology. University of the Basque Country (UPV/EHU). Leioa, Spain.*
**Jorge Olivares-Arancibia.** *AFySE Group. Research in Physical Activity and School Health. School of Physical Education Pedagogy. Faculty of Education. University of las Américas. Santiago, Chile.*
**Pedro Valdivia-Moral.** *Department of Didactics of Musical, Plastic and Corporal Expression. Faculty of Education. University of Granada. Granada, Spain.*

## ABSTRACT

Background/objectives. This study aims to analyse the speed differences between men and women in the 400 meters during the Paris 2024 Olympic Games. Average speeds in each segment of the race were evaluated, highlighting gender variations and performance across the different rounds of the competition. Methods. A descriptive observational study was conducted using data from 208 athletes (50% women). Average speeds per 50-meter segments were analysed across all rounds (heats, semifinals, and final), applying Student's t-tests to compare results between genders. The significance level was set at $p < .05$. Results. The average speeds showed significant differences between sexes in all segments of the race ($p < .05$). The largest difference was observed in the first 150 meters, where men outpaced women by a margin of 0.97 km/h. By 250 meters, the difference decreased to 0.43 km/h. In the final rounds, the winners reached maximum speeds of 36.87 km/h (men) and 32.48 km/h (women). Conclusion. Men exhibit a biomechanical advantage in the race's early stages, while both sexes strategically adjust their pacing in the final rounds. These findings suggest that gender differences in performance are linked to both physiological and biomechanical factors.
**Keywords**: Performance analysis, Competitive analysis, Biomechanics, Gender performance metrics, Olympic event outcomes, Endurance racing strategies.

**Cite this article as:**
de Souza-Lima, J., Giakoni-Ramírez, F., Muñoz-Strale, C., Yáñez-Sepúlveda, R., Duclos-Bastias, D., Cortés-Roco, G., Bonilla, D. A., Olivares-Arancibia, J., & Valdivia-Moral, P. (2025). Analysis of speeds in the 400-meter hurdles and gender differences: A study from the Paris 2024 Olympics. *Journal of Human Sport and Exercise, 20*(2), 435-445. https://doi.org/10.55860/fptent35

✉ **Corresponding author.** *Faculty of Education and Social Sciences, Universidad Andres Bello, Las Condes, Santiago 7550000, Chile.*
E-mail: josivaldo.desouza@unab.cl
Submitted for publication November 04, 2024.
Accepted for publication December 17, 2024.
Published February 10, 2025.
Journal of Human Sport and Exercise. ISSN 1988-5202.

**doi:** https://doi.org/10.55860/fptent35

## INTRODUCTION

Athletics has been a central field of study in research on human physical abilities for decades, with speed events playing a crucial role in understanding sports performance (Jeffreys, 2024; Paul et al., 2016). Among these events, the 400-meter sprint stands out as one of the most challenging, requiring a unique combination of explosive speed and sustained endurance. This event draws attention not only due to its physiological complexity but also because of the performance differences observed between elite athletes of different sexes (Guex, 2012; McClelland & Weyand, 2022).Previous research has identified significant differences in the performance of male and female athletes in sprint events, particularly in shorter distances such as the 100 and 200 meters (Atkinson et al., 2024; Zhang et al., 2021). Specifically, men tend to reach higher maximum speeds due to differences in muscle mass, power output, and anaerobic capacity. However, the 400-meter event introduces an additional variable: the athletes' ability to maintain speed over a longer distance, which requires a complex interaction between anaerobic and aerobic systems (Iskra et al., 2024).

In this context, the Paris 2024 Olympic Games provided a unique opportunity to study the performance of elite athletes under peak competitive conditions. Sex differences in the 400-meter performance during the Olympics have yet to be explored in depth, despite the significance of this event in the Olympic program. This analysis is crucial for understanding how the physiological characteristics of men and women impact their performance in races that demand both speed and endurance (Iskra et al., 2024; Santisteban et al., 2022).

Performance in the 400 meters is intrinsically linked to how efficiently athletes can utilize their energy systems (Le Hyaric et al., 2024). Research has shown that while women have a lower capacity for producing maximum power, they tend to be more efficient in utilizing the aerobic system during longer-distance races (Miller, 2023; Santisteban et al., 2022; Tiller et al., 2021). This suggests that the performance differences between men and women in the 400 meters may be more related to energy efficiency than pure speed (Helgerud et al., 2023).

Therefore, this study aims to analyse the differences in running speed between male and female athletes in the 400 meters during the Paris 2024 Olympic Games. Through a detailed analysis of speed variations across different race segments, the study seeks to provide new insights into current gender differences and their influence on performance in this Olympic event, contributing to the development of specific training programs.

## MATERIAL AND METHODS

### *Study design*

This descriptive observational study is based on performance data from 208 speed records of athletes who participated in the 400-meter event during the Paris 2024 Olympic Games.

### *Participants*

The dataset includes 104 records from female athletes and 104 from male athletes. Since some athletes competed in multiple rounds (heats, semifinals, and finals), the same athletes may be represented more than once in the dataset.

### *Inclusion and exclusion criteria*

The inclusion criteria required athletes to be officially registered in the 400-meter event. Exclusion criteria included failure to start the race, sustaining an injury during the race, or finishing the race by walking. Based on these criteria, 2 female athletes and 13 male athletes were excluded from the study.

 

### *Ethical considerations*

This study adheres to the principles of the Declaration of Helsinki (World Medical Association, 2013), ensuring ethical conduct and transparency in data collection and analysis. Obtaining informed consent was not required since the data is publicly available and does not involve direct interventions with participants.

### *Procedures*

Information for each race segment (50 m, 100 m, 150 m, etc.) was extracted directly from the official Olympics website (Olympics, 2024). The split times for each segment were downloaded in PDF format and subsequently input into an Excel template for analysis. The results included time and average speed measurements for each round and by gender. This approach enabled a detailed analysis of the athletes' performance and provided a solid foundation for the statistical interpretation of the results obtained during the Olympic competition.

### *Statistical analysis*

A comparative analysis of running speeds between men and women was conducted. Average speeds per 50-meter segment were calculated for each gender across all rounds of the competition, including heats, semifinals, and finals, using the formula ($v = d/t$). The data was organized into tables displaying the means and standard deviations of the average speeds for each race segment. To assess gender differences in speed, independent samples t-tests were applied. The significance level was set at $p < .05$. The graphical analysis was performed in Google Colab®, utilizing the Matplotlib and Pandas libraries in Python to generate visualizations comparing athlete performance across each round. The comparisons covered all stages of the competition, including heats, repechages, semifinals, and the final. The collected data was processed using Jamovi software, version 2.3.21, where average speeds were calculated from the recorded times. These speeds were first calculated in meters per second and then converted to kilometres per hour for more detailed analysis. Additionally, a heatmap of Bonferroni-adjusted *p*-values was generated to evaluate the statistical significance of the differences in speeds across various distances. This allowed for identifying which distance comparisons showed statistically significant differences after the adjustment was applied.

## RESULTS

Of the 208 participants, 50% were women. The comparative analysis of average speeds in the 400-meter race revealed significant differences between men and women across all segments ($p < .05$). In the first 150 meters, men recorded an average speed 0.97 km/h higher than women, representing the largest difference observed throughout the race. As the distance progressed, these differences diminished, reaching 0.43 km/h at 250 meters. The final speeds of the male and female winners also reflected a significant increase as they advanced through the rounds, with the highest performance observed in the final round. These differences in speed between genders suggest an advantage for men in the early stages of the race, while both sexes demonstrated strategic pacing adjustments in the final rounds.

Table 1 presents the average speeds and times of athletes throughout the 400 meters, divided into 50-meter segments. The values are shown separately by gender and across the different rounds of the competition, including heats, repechage, semifinals, and the final.

Table 2 shows the average speeds (in kilometres per hour) of athletes in different segments of the 400-meter race, broken down by gender and round. The columns represent the speeds reached in the 50, 100, 150, 200, 250, 300, 350, and 400-meter segments.

Table 1. General characteristics of average times and speeds in 400 meters by gender and round.

| Gender | Round | Athletes (n) | Average Time (s) | Speed (km/h) |
|---|---|---|---|---|
| Female | Final | 8 | 27.0 ± 0.3 | 29.5 ± 0.4 |
| Female | Semi 3 | 8 | 27.6 ± 0.4 | 28.7 ± 0.4 |
| Female | Semi 2 | 8 | 27.7 ± 0.4 | 28.8 ± 0.4 |
| Female | Semi 1 | 8 | 27.5 ± 0.5 | 28.7 ± 0.6 |
| Female | Repechage 4 | 6 | 28.1 ± 0.3 | 28.2 ± 0.2 |
| Female | Repechage 3 | 7 | 28.1 ± 0.3 | 28.2 ± 0.9 |
| Female | Repechage 2 | 7 | 28.3 ± 0.3 | 28.0 ± 0.3 |
| Female | Repechage 1 | 6 | 28.1 ± 0.2 | 28.2 ± 0.2 |
| Female | Serie 6 | 7 | 28.0 ± 0.6 | 28.1 ± 0.5 |
| Female | Serie 5 | 8 | 28.1 ± 0.5 | 28.3 ± 0.6 |
| Female | Serie 4 | 8 | 27.7 ± 0.3 | 28.6 ± 0.3 |
| Female | Serie 3 | 8 | 27.9 ± 0.5 | 28.4 ± 0.6 |
| Female | Serie 2 | 7 | 27.9 ± 0.3 | 28.5 ± 0.4 |
| Female | Serie 1 | 8 | 27.9 ± 0.4 | 28.5 ± 0.4 |
| Male | Final | 8 | 24.3 ± 0.4 | 32.9 ± 0.6 |
| Male | Semi 3 | 8 | 24.5 ± 0.3 | 32.5 ± 0.3 |
| Male | Semi 2 | 8 | 24.5 ± 0.3 | 32.6 ± 0.4 |
| Male | Semi 1 | 8 | 26.4 ± 4.9 | 31.7 ± 2.3 |
| Male | Repechage 4 | 6 | 25.1 ± 0.1 | 32.0 ± 0.3 |
| Male | Repechage 3 | 6 | 25.0 ± 0.1 | 32.0 ± 0.2 |
| Male | Repechage 2 | 7 | 25.3 ± 0.1 | 31.7 ± 0.1 |
| Male | Repechage 1 | 7 | 25.2 ± 0.1 | 31.7 ± 0.2 |
| Male | Serie 6 | 8 | 25.0 ± 0.2 | 32.0 ± 0.3 |
| Male | Serie 5 | 8 | 24.9 ± 0.3 | 32.0 ± 0.4 |
| Male | Serie 4 | 7 | 24.8 ± 0.4 | 32.2 ± 0.7 |
| Male | Serie 3 | 8 | 24.8 ± 0.3 | 32.1 ± 0.3 |
| Male | Serie 2 | 8 | 24.7 ± 0.2 | 32.4 ± 0.4 |
| Male | Serie 1 | 7 | 25.0 ± 0.2 | 32.0 ± 0.3 |

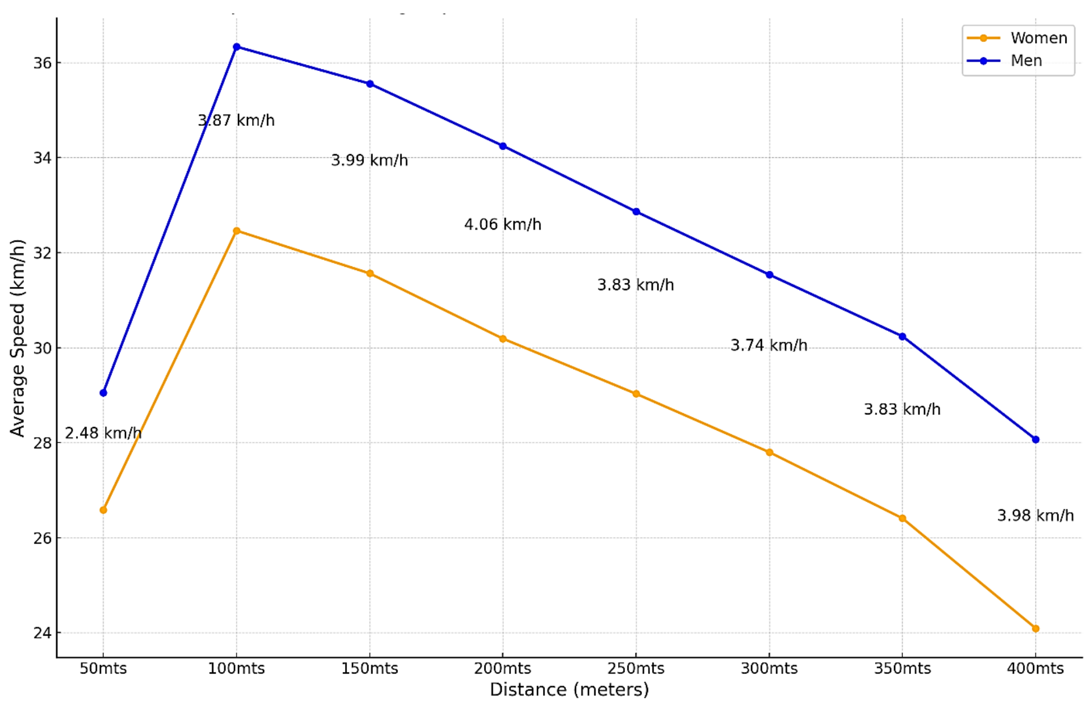


Figure 1. Comparison of average speeds between women and men across distances.

Table 2. Average (km/h) in different segments of the 400 meters: analysis by sex and round.

| Gender | Round | 50mts | 100mts | 150mts | 200mts | 250mts | 300mts | 350mts | 400mts |
|---|---|---|---|---|---|---|---|---|---|
| Female | Final | 27.3 ± 0.4 | 33.3 ± 0.5 | 32.6 ± 0.6 | 31.3 ± 0.5 | 29.8 ± 0.7 | 28.5 ± 0.6 | 27.6 ± 0.6 | 25.4 ± 0.7 |
| Female | Semi 3 | 26.8 ± 0.5 | 32.6 ± 0.5 | 31.9 ± 0.5 | 30.5 ± 0.6 | 29.2 ± 0.5 | 27.7 ± 0.5 | 26.6 ± 0.6 | 24.4 ± 0.7 |
| Female | Semi 2 | 26.6 ± 0.5 | 32.4 ± 0.6 | 31.7 ± 0.7 | 30.4 ± 0.4 | 29.0 ± 0.3 | 28.1 ± 0.3 | 27.0 ± 0.5 | 25.2 ± 0.8 |
| Female | Semi 1 | 27.1 ± 0.4 | 33.0 ± 0.5 | 32.3 ± 0.6 | 30.6 ± 1.6 | 29.6 ± 1.9 | 27.7 ± 0.7 | 26.1 ± 0.6 | 23.5 ± 1.1 |
| Female | Repechage 4 | 26.3 ± 0.3 | 32.2 ± 0.2 | 31.1 ± 0.3 | 29.8 ± 0.2 | 28.8 ± 0.2 | 27.6 ± 0.4 | 26.0 ± 0.7 | 23.6 ± 0.6 |
| Female | Repechage 3 | 26.1 ± 0.2 | 32.0 ± 0.5 | 31.1 ± 0.4 | 29.9 ± 0.3 | 28.6 ± 0.4 | 27.3 ± 0.7 | 26.0 ± 0.9 | 23.9 ± 0.9 |
| Female | Repechage 2 | 26.4 ± 0.6 | 32.1 ± 0.9 | 31.6 ± 0.6 | 30.2 ± 0.5 | 28.8 ± 0.2 | 27.7 ± 0.6 | 26.0 ± 1.3 | 23.7 ± 1.8 |
| Female | Repechage 1 | 26.2 ± 0.3 | 32.0 ± 0.5 | 30.8 ± 0.3 | 29.8 ± 0.4 | 28.9 ± 0.5 | 27.7 ± 0.5 | 26.2 ± 0.6 | 24.2 ± 0.6 |
| Female | Serie 6 | 26.8 ± 0.6 | 32.6 ± 0.8 | 31.5 ± 0.8 | 30.0 ± 0.6 | 28.1 ± 1.7 | 28.0 ± 1.8 | 25.6 ± 1.1 | 22.5 ± 0.8 |
| Female | Serie 5 | 26.3 ± 0.6 | 32.1 ± 0.5 | 31.2 ± 0.7 | 29.9 ± 0.7 | 28.8 ± 0.8 | 27.7 ± 0.9 | 26.3 ± 1.0 | 24.2 ± 1.0 |
| Female | Serie 4 | 26.4 ± 0.5 | 32.5 ± 0.2 | 31.7 ± 0.3 | 30.6 ± 0.3 | 29.7 ± 1.0 | 27.8 ± 1.0 | 26.2 ± 0.5 | 24.2 ± 0.9 |
| Female | Serie 3 | 26.7 ± 0.6 | 32.4 ± 0.9 | 31.3 ± 1.0 | 30.0 ± 0.9 | 28.8 ± 0.5 | 27.5 ± 0.5 | 26.7 ± 2.1 | 23.6 ± 1.6 |
| Female | Serie 2 | 26.5 ± 0.5 | 32.3 ± 0.5 | 31.2 ± 0.3 | 29.8 ± 0.4 | 29.0 ± 0.3 | 28.2 ± 0.6 | 26.5 ± 0.8 | 24.3 ± 0.9 |
| Female | Serie 1 | 26.6 ± 0.5 | 32.7 ± 0.6 | 31.3 ± 0.5 | 29.7 ± 0.4 | 29.2 ± 1.0 | 27.6 ± 0.9 | 26.5 ± 0.7 | 24.3 ± 1.0 |
| Male | Final | 29.5 ± 0.7 | 37.3 ± 0.8 | 36.5 ± 1.0 | 35.0 ± 0.9 | 33.3 ± 0.9 | 32.0 ± 0.8 | 30.7 ± 1.0 | 29.0 ± 1.3 |
| Male | Semi 3 | 29.6 ± 0.3 | 37.2 ± 0.6 | 36.4 ± 0.6 | 34.7 ± 0.5 | 32.7 ± 0.7 | 31.4 ± 0.6 | 30.1 ± 0.5 | 27.9 ± 0.7 |
| Male | Semi 2 | 29.4 ± 0.4 | 36.8 ± 0.7 | 36.1 ± 0.4 | 34.8 ± 0.4 | 33.5 ± 0.4 | 31.6 ± 0.4 | 30.2 ± 0.4 | 28.5 ± 0.9 |
| Male | Semi 1 | 29.2 ± 0.6 | 36.4 ± 0.6 | 35.5 ± 1.0 | 34.5 ± 0.8 | 33.3 ± 0.6 | 31.3 ± 1.4 | 27.3 ± 9.4 | 26.0 ± 8.6 |
| Male | Repechage 4 | 28.5 ± 0.4 | 35.6 ± 0.4 | 34.7 ± 0.3 | 33.7 ± 0.4 | 32.5 ± 0.6 | 31.6 ± 0.6 | 30.6 ± 0.4 | 28.9 ± 0.6 |
| Male | Repechage 3 | 28.9 ± 0.3 | 35.7 ± 0.6 | 34.6 ± 0.2 | 33.6 ± 0.2 | 32.7 ± 0.4 | 31.8 ± 0.3 | 31.2 ± 1.5 | 27.7 ± 1.3 |
| Male | Repechage 2 | 28.6 ± 0.4 | 35.2 ± 0.7 | 34.1 ± 0.4 | 33.3 ± 0.1 | 32.5 ± 0.4 | 31.5 ± 0.5 | 30.2 ± 0.3 | 28.5 ± 0.3 |
| Male | Repechage 1 | 28.6 ± 0.2 | 35.4 ± 0.6 | 35.3 ± 0.5 | 33.8 ± 0.3 | 32.0 ± 0.3 | 31.1 ± 0.6 | 29.7 ± 0.9 | 27.5 ± 1.1 |
| Male | Serie 6 | 28.8 ± 0.6 | 36.2 ± 0.6 | 35.5 ± 0.5 | 34.1 ± 0.4 | 32.6 ± 0.2 | 31.2 ± 0.5 | 29.7 ± 0.8 | 27.5 ± 1.0 |
| Male | Serie 5 | 29.2 ± 0.6 | 36.3 ± 0.5 | 35.4 ± 0.5 | 33.9 ± 0.4 | 32.5 ± 0.4 | 31.0 ± 0.4 | 30.0 ± 0.7 | 27.6 ± 1.2 |
| Male | Serie 4 | 28.7 ± 0.5 | 36.4 ± 0.9 | 35.7 ± 0.7 | 34.5 ± 0.5 | 33.1 ± 0.5 | 31.6 ± 0.6 | 30.3 ± 0.7 | 27.4 ± 2.9 |
| Male | Serie 3 | 29.1 ± 0.3 | 36.4 ± 0.8 | 35.4 ± 0.6 | 34.1 ± 0.4 | 32.8 ± 0.4 | 31.5 ± 0.4 | 30.2 ± 0.5 | 27.6 ± 0.6 |
| Male | Serie 2 | 29.1 ± 0.4 | 36.3 ± 0.6 | 35.9 ± 0.6 | 34.6 ± 0.7 | 33.2 ± 0.5 | 31.7 ± 0.5 | 30.2 ± 0.7 | 28.1 ± 1.1 |
| Male | Serie 1 | 28.8 ± 0.5 | 36.0 ± 0.7 | 35.4 ± 0.4 | 34.0 ± 0.5 | 32.6 ± 0.6 | 31.6 ± 0.4 | 29.9 ± 0.5 | 27.6 ± 0.6 |

Figure 1 illustrates the average speed differences between men and women in each segment of a 400-meter race, considering all rounds. The figure shows that men consistently maintain higher speeds than women across all segments of the race. The most pronounced differences occur in the first 150 meters, where the speed gap reaches its peak. As the race progresses, these differences slightly decrease but remain consistently in favour of the men throughout the entire race.

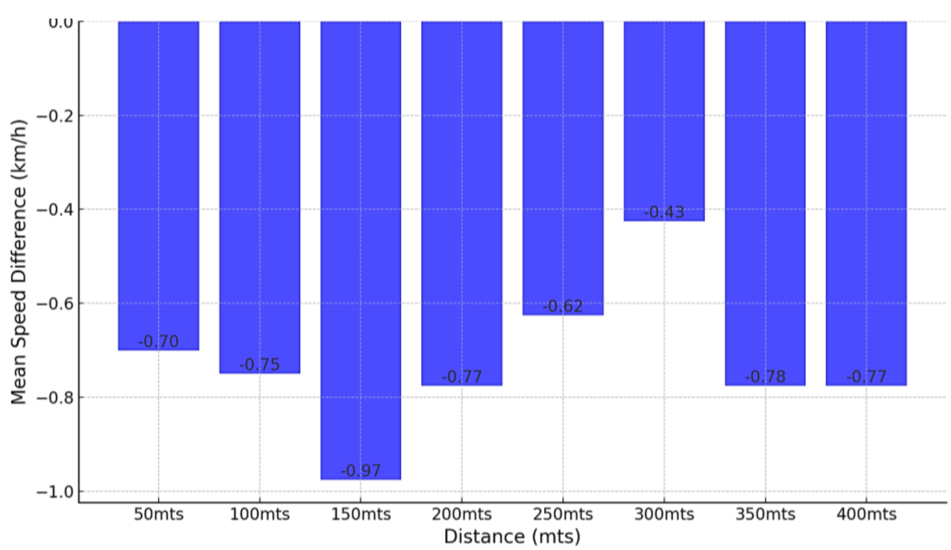


Figure 2. Mean speed differences between men and woman by distance (all rounds).

Figure 2 displays the average speed differences between men and women in each 50-meter segment of a 400-meter race, considering all rounds. The bars indicate that men run faster than women across all segments of the race. The most pronounced difference is observed in the 150-meter segment, where men's average speed exceeds women's by 0.97 km/h. As the race progresses, the speed difference slightly decreases but remains steady at around 0.77 km/h in the final segments of the race.

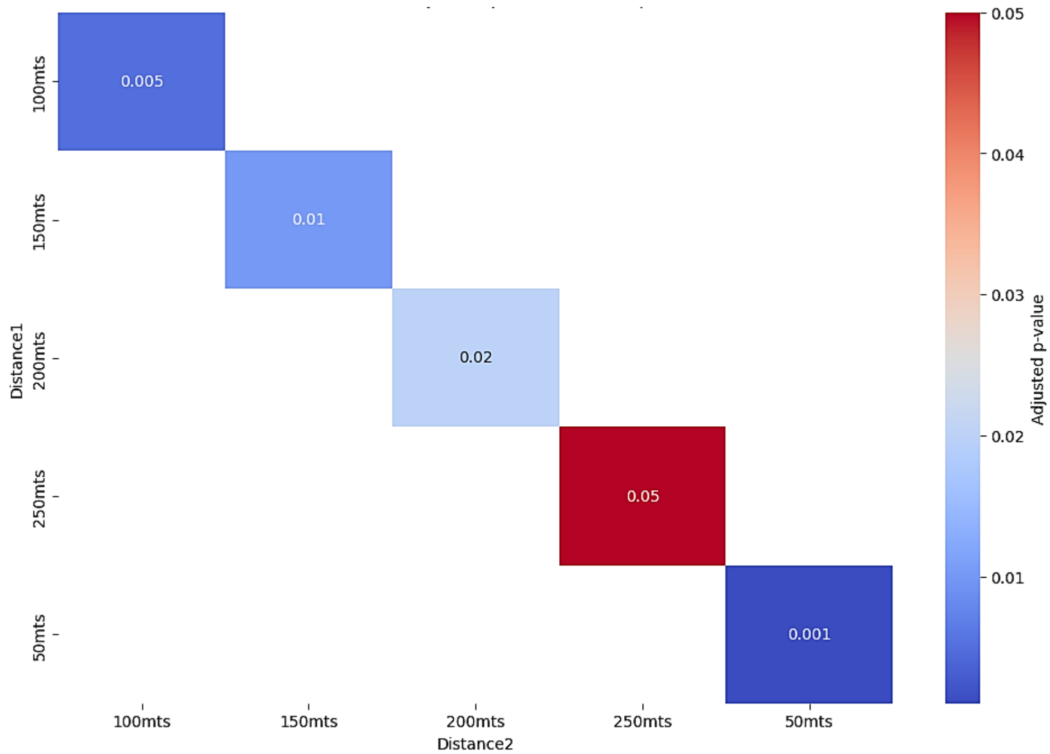


Figure 3. Heatmap of Bonferroni adjusted *p-values* for velocity differences across distances.

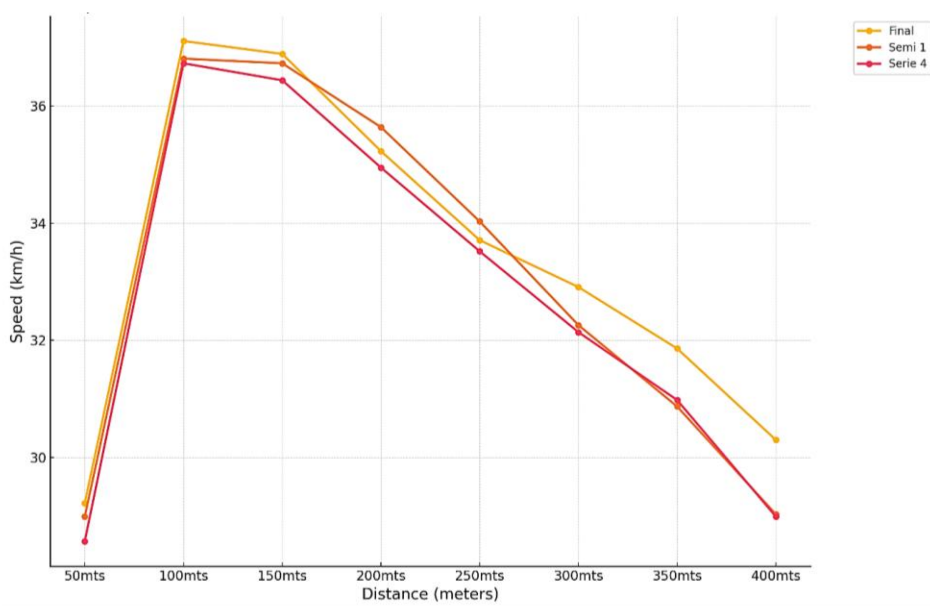


Figure 4. Speed evolution of de male winner (Hall Quincy) across rounds and distances.

 

Heatmap 3 displays Bonferroni-adjusted *p*-values, highlighting the statistically significant differences in average speeds across various distances. Blue cells indicate comparisons with low *p*-values, such as between 50 and 100 meters, which are statistically significant, while red cells, such as between 250 and 50 meters, indicate less significant comparisons.

Figure 4 illustrates the speed evolution of the male winner (Hall Quincy) across different segments of the 400-meter race throughout the rounds (Heat 4, Semifinal 1, and Final). It shows that Quincy generally reached his highest speeds in the final, particularly in the first 150 meters, where his speed exceeded 36 km/h. After this point, his speed began to decline similarly in all rounds, showing a progressive deceleration towards the 400-meter mark. Comparing the different rounds, a performance improvement is evident in the final compared to the heats and semifinals.

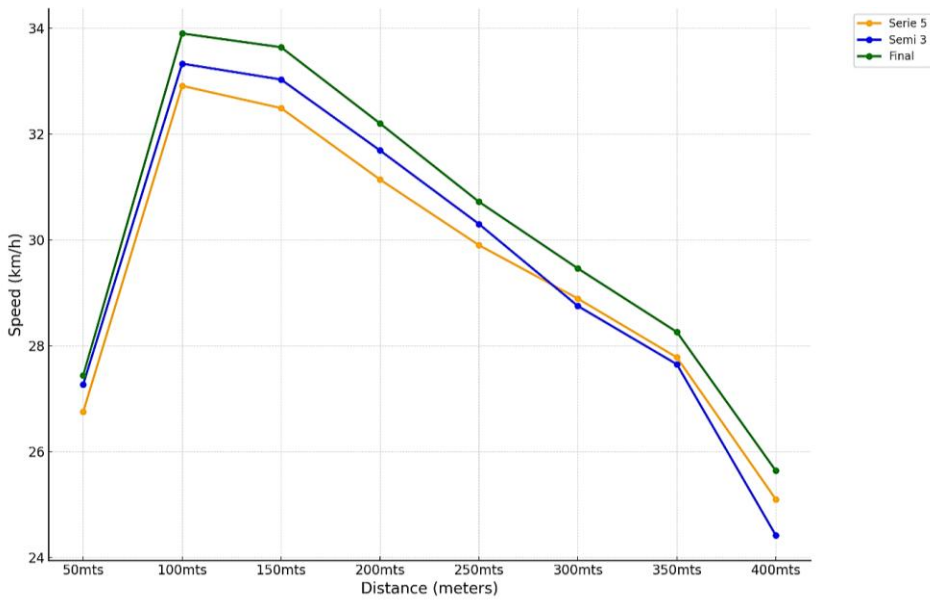


Figure 5. Speed evolution of de female winner (Marileidy Paulino) across rounds and distances.

Figure 5 illustrates the speed evolution of the female winner across different segments of the 400-meter race throughout the rounds (Heat 5, Semifinal 3, and Final). It shows that Marileidy reached her highest speeds in the final, with a peak speed of approximately 34 km/h in the first 150 meters. After this point, her speed progressively declined throughout the race in all rounds. However, an improvement in her performance is evident in the final compared to the preliminary rounds (Heat and Semifinal), where she maintained higher speeds during the race.

## DISCUSSION

It was observed that the average speed progressively decreases as athletes advance through the total distance of the race, with the most pronounced speed differences occurring in the first 150 meters, particularly between men and women. Previous studies indicate that elite athletes reach maximum speeds of 10.12 m/s for men and 8.96 m/s for women between the 50 and 100-meter segments. We converted these values to kilometres per hour (km/h) using the formula 1 m/s = 3.6 km/h, resulting in 36.43 km/h for men and 32.26 km/h for women. In our study, the maximum speeds were 36.87 km/h for men and 32.48 km/h for women, aligning with the reported values. Additionally, we observed an average fatigue index of 22.99% in elite runners, similar to previous findings, suggesting that elite athletes adopt an aggressive pacing strategy, experiencing a greater drop in speed over the final 100 meters. These findings reinforce the importance of physiological and biomechanical factors in maintaining performance, even under conditions of advanced fatigue (Hanon & Gajer, 2009).

In 400-meter race performance, energy systems play a key role in the interaction between anaerobic and aerobic metabolism. According to other authors, energy for these races is derived 59% from the anaerobic system and 41% from the aerobic system for men. In the case of women, this ratio is 55% and 45%, respectively (Duffield et al., 2005). Our findings align with these results, as we observed a strong reliance on anaerobic reserves during the first half of the race, followed by an increased aerobic contribution towards the end, when fatigue begins to set in. In our study, elite runners reached maximum speeds of 36.87 km/h for men and 32.48 km/h for women in the first 100 meters. However, by the end of the race, speed declined due to lactate accumulation and reduced phosphocreatine (PCr), as noted by Dall Pupo et al. The balance between these metabolic pathways, along with the capacity for muscle recruitment and the body's buffering ability to manage anaerobic byproducts, allows athletes to maximize their performance during the sprint (Dal Pupo et al., 2013).

As mentioned earlier, the anaerobic system is more heavily utilized in men (59%) than in women (55%). Although both sexes exhibit similar patterns of speed reduction, men tend to maintain a higher average speed across all distances, highlighting significant physiological differences between genders. This finding is consistent with previous studies indicating that elite athletes optimize their effort distribution, sustaining high speeds until the final segments of the race, where metabolic conditions, such as lactate accumulation and reduced muscle pH, significantly impact performance. In this context, it has been reported that blood lactate levels can reach up to 20.5 mmol/L in 400-meter runners, contributing to muscle fatigue and impairing the muscles' ability to maintain efficient contraction (Cicchella, 2022). These metabolic factors partly explain why; despite exhibiting similar patterns of speed reduction, men are able to maintain higher speeds, likely due to a greater capacity to manage acidosis and the fatigue resulting from lactate accumulation.

It is important to highlight that the greatest speed reduction between men and women occurs in the first 150 meters, with a difference of -0.97 km/h. This phenomenon may be related to male runners' ability to maintain a better balance between stride frequency and stride length during the early stages of the race. Previous research indicates that elite runners tend to reach their peak stride frequency between the first 50 and 100 meters, while stride length peaks between 100 and 150 meters, suggesting a biomechanical advantage for men in these key segments of the race (Gajer et al., 2007). In contrast, in women, stride frequency tends to decrease more rapidly as muscle fatigue accumulates, affecting their performance in the later segments of the race (Guex, 2012). These findings underscore the significant biomechanical and physiological differences between the sexes during the 400-meter race.

In terms of comparison between male and female winners, it is observed that men are able to maintain more consistent performance across the different rounds, suggesting better effort management and greater resistance to fatigue. This may be related to differences in lactate accumulation, which in male 400-meter runners can reach up to 17.3 mmol/L, indicating a higher capacity to tolerate acidosis compared to women (Kalih & Rahmadani, 2021). In contrast, although women also manage to maintain similar speeds across rounds, their speed decline is more pronounced in the second half of the race due to greater muscle fatigue. This is consistent with previous studies, which showed that asymmetric muscle activity and fatigue in the lower limbs significantly increase during the second half of the race, affecting mechanical efficiency and performance in female athletes (Iwańska et al., 2021).

 

The findings of the present study limit the complete verification of the analyses of the 400 meters. However, a theoretical and explanatory influence of fatigue and lactate accumulation on performance, particularly during the final phases of the race, was observed. This influence appears to be linked to differences in the anaerobic and aerobic systems' capacity to sustain speed, resulting in a greater negative impact on women, especially in the later segments of the race. Although the results suggest a greater ability in men to manage acidosis and maintain biomechanical efficiency, further research is needed to confirm these findings. Future studies should focus on analysing the precise interactions between muscle activity and kinematic variables throughout the entire race, especially concerning effort distribution and muscle fatigue. These results highlight the importance of optimizing both the energetic and biomechanical aspects of training to maximize performance in this demanding discipline.

One of the main limitations of this study is the lack of control over individual variables, such as differences in training experience, body composition, and muscle fibre distribution among the participants, which may have influenced the observed performance. Additionally, the sample focused on elite runners, limiting the generalizability of the results to athletes at other performance levels. Future studies could benefit from a more diverse sample and a more detailed focus on the individual characteristics that affect the physiological and biomechanical response during 400-meter races.

## CONCLUSION

In this study, it was determined that elite runners participating in the 400-meter event primarily rely on the anaerobic system during the first half of the race, followed by a greater aerobic contribution towards the end. We observed that men are able to maintain higher speeds than women, likely due to better management of acidosis and muscle fatigue. Additionally, men sustain a better balance between stride frequency and stride length in the early stages of the race, contributing to their superior performance compared to women, who experience a greater decrease in speed during the second half. These findings highlight key differences in the physiological and biomechanical strategies between the sexes.

## AUTHOR CONTRIBUTIONS

Study concept and design: JSL, RYS PVM; Search strategy: JSL and DB; Literature identification and selection: JSL, GCR, JOL and FGR; Data extraction and quality assessment: JSL, FGR, DDB; Narrative synthesis: PVM, JSL and DB; Manuscript writing: JSL, RYS, GCR , JOL and PVM; Study supervision: FGR, DB, PVM, CMS, RYS. FGR conceived the study, participated in its design and coordination, and contributed to manuscript writing. All authors read and approved the final version of the manuscript.

## SUPPORTING AGENCIES

No funding agencies were reported by the authors.

## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

## REFERENCES


Atkinson, M., James, J., Quinn, M., Senefeld, J., & Hunter, S. (2024). Sex differences in track and field elite youth. https://doi.org/10.51224/SRXIV.324

Cicchella, A. (2022). The Problem of Effort Distribution in Heavy Glycolytic Trials with Special Reference to the 400 m Dash in Track and Field. Biology, 11(2), 216. https://doi.org/10.3390/biology11020216

Dal Pupo, J., Arins, F. B., Antonacci Guglielmo, L. G., Rosendo da Silva, R. C., Moro, A. R. P., & Dos Santos, S. G. (2013). Physiological and neuromuscular indices associated with sprint running performance. Research in sports medicine, 21(2), 124-135. https://doi.org/10.1080/15438627.2012.757225

Duffield, R., Dawson, B., & Goodman, C. (2005). Energy system contribution to 400-metre and 800-metre track running. Journal of sports sciences, 23(3), 299-307. https://doi.org/10.1080/02640410410001730043

Gajer, B., Hanon, C., & Thepaut-Mathieu, C. (2007). Velocity and stride parameters in the 400 metres. New Studies in Athletics, 22(3), 39-46.

Guex, K. (2012). Kinematic analysis of the women's 400 m hurdles. New Studies in Athletics, 27(1/2), 41-51.

Hanon, C., & Gajer, B. (2009). Velocity and stride parameters of world-class 400-meter athletes compared with less experienced runners. The Journal of Strength & Conditioning Research, 23(2), 524-531. https://doi.org/10.1519/JSC.0b013e318194e071

Helgerud, J., Hov, H., Mehus, H., Balto, B., Boye, A., Finsås, L., Hoff, J., & Wang, E. (2023). Aerobic high-intensity intervals improve V̇O2max more than supramaximal sprint intervals in females, similar to males. Scandinavian Journal of Medicine & Science in Sports, 33(11), 2193-2207. https://doi.org/10.1111/sms.14470

Iskra, J., Gupta, S., Przednowek, K., V Best, R., & Stanula, A. (2024). The impact of physique on strategy and performance in the 400 m hurdles race among elite male athletes. Baltic Journal of Health and Physical Activity, 16(1), 4. https://doi.org/10.29359/BJHPA.16.1.04

Iwańska, D., Tabor, P., Grabowska, O., & Mastalerz, A. (2021). The symmetry of fatigue of lower limb muscles in 400 m run based on electromyoFigurey signals. Symmetry, 13(9), 1698. https://doi.org/10.3390/sym13091698

Jeffreys, I. (2024). Developing speed. Human Kinetics.

Kalih, B. S., & Rahmadani, E. A. (2021). Comparison of 800 Meter and 400 Meter Run Effects on The Increase Of Lactic Acid In Athletic Athlete. Gladi: Jurnal Ilmu Keolahragaan, 12(03), 61-67. https://doi.org/10.21009/GJIK.123.09

Le Hyaric, A., Aftalion, A., & Hanley, B. (2024). Modelling the optimization of world-class 400 m and 1,500 m running performances using high-resolution data. Frontiers in Sports and Active Living, 6, 1293145. https://doi.org/10.3389/fspor.2024.1293145

McClelland, E. L., & Weyand, P. G. (2022). Sex differences in human running performance: smaller gaps at shorter distances? Journal of Applied Physiology, 133(4), 876-885. https://doi.org/10.1152/japplphysiol.00359.2022

Miller, J. (2023). Anaerobic Capacity. In Laboratory Manual for Strength and Conditioning (pp. 133-147). Routledge. https://doi.org/10.4324/9781003186762-9

Olympics. (2024). Paris 2024 Olympic Sports. Olympics.com. Retrieved from [Accessed 2025, January 22]: https://olympics.com/es/paris-2024/calendario/11-agosto

Paul, D. J., Gabbett, T. J., & Nassis, G. P. (2016). Agility in team sports: Testing, training and factors affecting performance. Sports medicine, 46, 421-442. https://doi.org/10.1007/s40279-015-0428-2

Santisteban, K. J., Lovering, A. T., Halliwill, J. R., & Minson, C. T. (2022). Sex differences in VO2max and the impact on endurance-exercise performance. International journal of environmental research and public health, 19(9), 4946. https://doi.org/10.3390/ijerph19094946


 

Tiller, N. B., Elliott-Sale, K. J., Knechtle, B., Wilson, P. B., Roberts, J. D., & Millet, G. Y. (2021). Do sex differences in physiology confer a female advantage in ultra-endurance sport? Sports medicine, 51(5), 895-915. https://doi.org/10.1007/s40279-020-01417-2

World Medical Association (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA, 310(20), 2191-2194. https://doi.org/10.1001/jama.2013.281053

Zhang, J., Lin, X.-Y., & Zhang, S. (2021). Correlation analysis of sprint performance and reaction time based on double logarithm model. Complexity, 2021(1), 6633326. https://doi.org/10.1155/2021/6633326